GCE

Mathematics

Unit **4730**: Mechanics 3

Advanced GCE

Mark Scheme for June 2016

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

1. **Annotations and abbreviations**

Annotation in scoris	Meaning
✓and ✘	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	Meaning
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

2.   **Subject-specific Marking Instructions for GCE Mathematics (OCR) Mechanics strand**

a   Annotations should be used whenever appropriate during your marking.

        The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

        For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b   An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

        Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c   The following types of marks are available.

        M
        A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

        A
        Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

        B
        Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d   When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep *' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e   The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f   Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.)

We are usually quite flexible about the accuracy to which the final answer is expressed and we do not penalise over-specification.

When a value is given in the paper
Only accept an answer correct to at least as many significant figures as the given value. This rule should be applied to each case.
When a value is not given in the paper
Accept any answer that agrees with the correct value to 2 s.f.

ft should be used so that only one mark is lost for each distinct accuracy error, except for errors due to premature approximation which should be penalised only once in the examination.

There is no penalty for using a wrong value for *g*. E marks will be lost except when results agree to the accuracy required in the question.

g   Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

h   For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Marks designated as cao may be awarded as long as there are no other errors. E marks are lost unless, by chance, the given results are established by equivalent working.

'Fresh starts' will not affect an earlier decision about a misread.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i   If a graphical calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers (provided, of course, that there is nothing in the wording of the question specifying that analytical methods are required). Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j   If in any case the scheme operates with considerable unfairness consult your Team Leader.

		Answer	**Marks**	**Guidance**	
1	**(i)**	$0.3 \times 0.4 + I_x = 0.3 \times 0.6 \cos 30°$ $I_y = 0.3 \times 0.6 \sin 30°$ Magnitude of I = 0.0969 (Ns) 68.3° from original direction OR correct triangle of momentum $I^2 = 0.18^2 + 0.12^2 - 2 \times 0.18 \times 0.12 \times \cos 30°$ $I = 0.096890$ (Ns) 68.26° from original direction	M1 M1 A1 A1 **4** (M1) (A1) (A1) (A1)	$I_x = (\pm) \, 0.035884572$ $I_y = (\pm) \, 0.09$ CAO Accept 111.74° if clear on diagram Allow for wrong angle CAO Accept 111.74° if clear on diag.	Similar with velocities. 0.096890 68.26. Direction must be clear in words or on diagram Similar with velocities. Or slip in figure
	(ii)	Magnitude = 0.0969 N Direction opposite to (i) clearly shown and labelled or stated	B1ft B1ft **2**	 Accept direction at angle 141.7° with direction of 0.6 m s^{-1} motion	 If total 0 scored, allow SC1 for 38.3° or 68.3° seen
2	**(i)**	$3\cos 2t \; = \; 0.2\dfrac{\mathrm{d}v}{\mathrm{d}t}$ $7.5\sin 2t = v \, (+c)$ oe $v = 7.5\sin 2t + 4$ 11.5 (ms^{-1}) and -3.5 (ms^{-1})	M1* *M1 A1 A1 **4**	Use of F = ma; condone wrong / missing 0.2 and wrong sign Attempt to integrate, one side correct; condone missing c, CAO Depends on both M marks and fully correct working	
	(ii)	$x = -\dfrac{15}{4}\cos 2t + 4t \, (+c)$ Ave speed is their distance$/\dfrac{\pi}{2}$ $\left(\dfrac{15}{4} + 6\pi\right) - \left(-\dfrac{15}{4} + 4\pi\right)$ 8.77 (ms^{-1})	M1* *M1 *M1 A1 **4**	Ft if (i) has sin or cos term $\{x(\tfrac{3}{2}\pi) - x(\pi)\}$ found; CAO Accept $\dfrac{15}{\pi} + 4$	No need to find c (3.75) $\left(\dfrac{15}{2} + 6\pi\right) - (+4\pi)$

		Answer	Marks	Guidance	
3	**(i)**	C of M $2m \times 5\cos\alpha - 3m \times 3\frac{1}{4}\cos\beta = 2ma + 3mb$	M1*	allow sign and number slips.	a and b are vels of A and B to right
		$2m\text{x}4 - 3m\text{x}1.25 = 2ma + 3mb$	A1	$(2a + 3b = 4.25)$	
		Newton's experimental law	M1*	Or equivalent; allow sign slips	
		$b - a = -\frac{2}{3}(-1.25 - 4)$	A1	$(b - a = 3.5)$	Consistent
		Attempt to solve simultaneous equations	*M1		
		$b = 2.25$ (m s^{-1})	A1	CAO	-2.25 if b defined to left
		$(a = -1.25$ so) speed of $A = 3.25$ (m s^{-1})	A1 **7**	CAO	
	(ii)	A and B both have same component of velocity perp to l o c	B1		
		After collision with wall B must move faster than A	B1	May be implied	
		Coeff of restitution > 5/9 (accept > 0.5 recurring, or 0.556)	B1 **3**	Do not allow ≥	Ignore $e \leq 1$, etc

	Answer	Marks	Guidance	
4	Initial energy $= \frac{15 \times 0.5^2}{2 \times 0.6}$	B1	3.125 (J) or $\frac{25}{8}$	
	$\frac{20x}{0.4} = \frac{15(0.5 - x)}{0.6}$	M1A1	x measured from B; other points possible	
	$x = \frac{1}{6}$ (m)	A1	OR $\frac{17}{30}$ from A, or $\frac{11}{60}$ from midpt	Or 1/3 + 0.6 from C
	$\frac{20 \times \left(\frac{1}{6}\right)^2}{2 \times 0.4}$ or $\frac{15 \times \left(0.5 - \frac{1}{6}\right)^2}{2 \times 0.6}$ seen	B1	Allow their $\frac{1}{6}$	Not their $\frac{17}{30}$ or $\frac{11}{60}$
	$KE = 3.125 - \frac{20 \times \left(\frac{1}{6}\right)^2}{2 \times 0.4} - \frac{15 \times \left(0.5 - \frac{1}{6}\right)^2}{2 \times 0.6}$	M1	Allow their $\frac{1}{6}$ $= (3.125) - 0.69444 - 1.3888$	$\frac{25}{8} - \frac{25}{36} - \frac{25}{18}$
	$= 1.04167$ (J)	A1 **7**	Or $\frac{37.5}{36}$ or $\frac{25}{24}$	$\frac{75}{72}$
	OR $KE = [3.125] - \frac{20x^2}{2 \times 0.4} - \frac{15(0.5 - x)^2}{2 \times 0.6}$	(M1)	All terms present	CTS $-37.5\left(\frac{1}{6} - x\right)^2 + \frac{37.5}{36}$
	Differentiate OR complete the square	(M1)	Allow slips	leads to max KE $= \frac{37.5}{36}$
	Max KE when $x = \frac{1}{6}$	(A1)	B1 & B1M1A1 as above	
	OR stationary when $3.125 = \frac{20x^2}{2 \times 0.4} + \frac{15(0.5 - x)^2}{2 \times 0.6}$	(M1A1)		
	$x = 0$ or $\frac{1}{3}$ so max EPE when $x = \frac{1}{6}$	(A1)	B1 & B1M1A1 as above	
	Or by SHM, $m\ddot{x} = \frac{15(0.5 - x)}{0.6} - \frac{20x}{0.4}$	(M1A1)	Or other x	
	$m\ddot{x} = -75\left(x - \frac{1}{6}\right)$	(A1)		
	Amplitude, $a = \frac{1}{6}$	(B1)		
	$\omega^2 = \frac{75}{m}$	(B1)		
	Max KE $= \frac{1}{2}m\left(\frac{1}{6}\right)^2 \times \frac{75}{m}$	(M1)		
	$\frac{25}{24}$ J (or 1.04)	(A1)		

		Answer	Marks	Guidance	
5	**(i)**	By energy $\frac{1}{2}m(4ag) = \frac{1}{2}mv^2 + mga(1 + \cos\theta)$ Use of $F = ma$ $T + mg\cos\theta = \dfrac{mv^2}{a}$ $T = 2mg - 3mg\cos\theta$ Slack when $\cos\theta = \frac{2}{3}$ Height is $\frac{5}{3}a$	M1 A1 M1 A1 M1 A1 **6**	Need correct 3 terms; allow wrong sign, missing/extra g, missing m / a; sin for cos correct Need 3 terms and g, allow sign slip, sin for cos Ft if their T has right form	$v^2 = 2ag - 2ag\cos\theta$
	(ii)	If $\theta > \pi/2$, $\frac{1}{2}mU^2 > mga$ $U > \sqrt{(2ag)}$ For no complete revolutions $\frac{1}{2}mU^2 < \frac{1}{2}mu^2 + 2mga$ and $mg = m\dfrac{u^2}{a}$ $U < \sqrt{(5ag)}$ OR Use $\frac{1}{2}mU^2 = \frac{1}{2}mv^2 + mga(1 + \cos\theta)$ and $T + mg\cos\theta = \dfrac{mv^2}{a}$ To get $T = m\dfrac{U^2}{a} - 2mg - 3mg\cos\theta$ oe When T = 0, $U^2 = 2ag + 3ag\cos\theta$ $(\theta = 0)$ gives $U < \sqrt{(5ag)}$ $(\theta = \frac{\pi}{2})$ gives $U > \sqrt{(2ag)}$	M1 A1 M1 M1 A1 **5** (M1) (A1) (M1) (A1) (A1)	Allow '=' for all M marks Allow $\geq$ Allow wrong sign Allow wrong sign Allow $\leq$ Allow $\leq, <$ Allow $\leq$ Allow $\geq$	u is vel at top $\sqrt{2ag} < U < \sqrt{5ag}$

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		Answer	Marks	Guidance	
6	**(i)**	Moments about A for AB	M1	Allow if sign errors, $\sin\theta$ / $\cos\theta$ present; dim correct	Allow sin/cos confusion.
		$Wl\dfrac{3}{5} + F2l\dfrac{4}{5} = R2l\dfrac{3}{5}$	A1	Allow sign errors	
		$3W + 8F = 6R$ oe	A1 **3**	CAO	
6	**(ii)**	Moments about A for AC	M1	Allow if sign errors, $\sin\theta$ / $\cos\theta$ present	Q is normal reaction at C. Allow sin/cos confusion.
		$2W2l\dfrac{4}{5} + G4l\dfrac{3}{5} = Q4l\dfrac{4}{5}$	A1	Allow sign errors $(16W + 12G = 16Q$ oe$)$	G is friction force at C
		$F = G$	B1		
		Solve with eqn from (i) and $R + Q = 3W$	M1		dep moments equation
		$R = \dfrac{73}{50}W$	A1	AG	Accept $1.46W$
		$Q = \dfrac{77}{50}W$	A1 **6**	If <4 marks, sc B1 for $R + Q = W + 2W$	Or $1.54W$
		Or moments about C for whole system	(M1)	Allow if sign errors, $\sin\theta$ / $\cos\theta$ present. Need 4 terms.	Allow sin/cos confusion.
		$2W \times 2l\frac{4}{5} + W\left(4l\frac{4}{5} + l\frac{3}{5}\right) - R\left(4l\frac{4}{5} + 2l\frac{3}{5}\right) = F\left(4l\frac{3}{5} - 2l\frac{4}{5}\right)$	(A1) (A1)	Allow sign errors Correct	
		$(35W - 22R = 4F)$			
		Solve with eqn from (i)	(M1)	Final A1A1 as main scheme	dep moments equation
	(iii)	Attempt to find $F\ (= G) = \dfrac{18}{25}W$ or $F\ (= G) = \dfrac{36}{73}R$	M1	Or 0.72 W Ft their normal forces if at least M1 in (i) and (ii)	Or use (i) with $F=\mu R$ and $R = \dfrac{73}{50}W$ M1A1
		AB	B1	Can be implied	$584\mu W = 438W - 150W$
		Coeff of friction $= \dfrac{18}{25}W \div \dfrac{73}{50}W$	M1	Or 0.72W/1.46W May see $\dfrac{18}{25}W \div \dfrac{77}{50}W$ at $C\left(\dfrac{36}{77}\right)$	Solve A1; B1 as scheme
		$\dfrac{36}{73}$ or $0.493(15)$	A1 **4**	CAO	

Answer	Marks	Guidance
7 **(i)** In equilibrium, $mg = \dfrac{24mge}{0.6}$ $(e = 0.025 \text{ m})$; OP = 0.625 m	M1 A1 **2**	Working essential, with $24mg$ and 0.6 used AG	
(ii) For Q falling 0.4m $v^2 = 2g \times 0.4$ $v = 2.8 \ (\text{m s}^{-1})$ For combined particle $3m \text{x} 2.8 = 4mV$ $V = 2.1 \ (\text{m s}^{-1})$	M1 A1 A1 **3**	Or $\frac{1}{2}mv^2 = mg \times 0.4$ Accept $\sqrt{(0.8g)}$ Valid method shown – no slips **AG**	
(iii) When a distance x below O $4mg - \dfrac{24mg(x-0.6)}{0.6} = 4ma$ $-10g(x - 0.7) = \ddot{x}$ (SHM about) a point 0.7 m below O $2.1^2 = 10g(a^2 - 0.075^2)$ amplitude $= 0.225$ (m)	M1 A1 B1 M1 A1 **5**	Or $4mg - \dfrac{24mg(x+0.1)}{0.6} = 4m\ddot{x}$ Accept a for $\ddot{x}$; $-10gx = \ddot{x}$ Allow their ω; any x	Allow sign error, m for $4m$ $4mg - \dfrac{24mgx}{0.6} = 4m\ddot{x}$ $-10g(x - 0.1) = \ddot{x}$ Use of $v = a\omega$ gains M1
(iv) $0.4 = \frac{1}{2}9.8t^2$; or $2.8 = 9.8t$ $0.075 = 0.225\sin(\sqrt{98}t)$ $\dfrac{1}{2}T = \dfrac{\pi}{\sqrt{98}}$ $0.1 = 0.225\sin(\sqrt{98}t)$ $v = (0.225\sqrt{98}\cos(\sqrt{98} \times 0.046523) \ (= 1.995)$ or $v^2 = 98(0.225^2 - 0.1^2)$ $0 = 1.99 - 9.8t$ Time $= 0.888$ s	M1 M1 M1 M1 M1 M1 A1 **7**	Falling dist 0.4 m: 0.285714 s Travel 0.075m to centre: 0.0343287 s Half period: 0.31734878 s Travel 0.1m above centre: 0.046523 s Speed when string becomes slack 1.995307 m s^{-1} Travel to highest point: 0.203602 s 0.8875175 **CAO**	Must be their 2.8 Allow their values; allow cos Allow for whole or part period Allow their values; allow cos Allow their values; allow sin Allow their values Dep M6

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